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Mosaic of various seral stages of vegetation in the *Satoyama*, the traditional rural landscape of Japan as an important habitat for butterflies

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Abstract Assemblage structures of butterflies were studied by the transect count method in Farm and Coppice landscapes in a *Satoyama*, the traditional rural landscape of Japan, around Mt Mikusa in northern Osaka, central Japan from April to October, 2004. Transects in Farm and Coppice landscapes were classified into three and six landscape components, respectively, according to vegetation and landscape. To analyze characteristics of butterfly assemblage structures in the *Satoyama*, the seral rank of each butterfly was determined based on seral stages in which the main larval food plants occur, and compositions of each seral rank species were compared among landscapes and landscape components. A total of 1322 individuals belonging to 56 species from seven families were recorded throughout the whole study area. Both species richness and density of butterflies were higher in Coppice landscape (46 and 20.4 respectively) than in Farm landscape (39 and 13.1 respectively), while species diversity ($1-\lambda$) and evenness (J') were higher in Farm landscape (0.91 and 0.75 respectively) than in Coppice landscape (0.85 and 0.66 respectively). Coppice landscape and the whole study area were characterized by the dominance of three dwarf bamboo feeders, *Lethe diana*, *L. sicelis* and *Neope goschkevitschii*. In addition, both species richness and densities of univoltine butterflies including grass, violet and deciduous oak tree feeders were abundant in Coppice landscape. Analysis based on the SR index revealed that species richness and densities of butterflies dependent on plants occuring in young forests and deciduous broad-leaved forests as larval foods were high in Coppice landscape, whereas those dependent on plants occuring in short to tall grasslands were high in Farm landscape. On the other hand, some species of intermediate rank showed a wide range of distribution in Farm and Coppice landscapes in the study area. The results demonstrate that butterflies dependent on plants in wide ranges of seral stages of vegetation inhabit *Satoyama*. The mosaic structure of vegetation in terms of the seral stage is important for conservation of species diversities of butterflies in *Satoyama*.

Key words Butterfly assemblage, seral stage, species diversity, Japan, *Satoyama*, coppice, farm, transect count.

Introduction

The "*Satoyama*" in a broad sense is the traditional rural landscape of Japan consisting of coppices (*Satoyama* in a narrow sense) and farmlands such as paddy fields and semi-natural grasslands (Ishii, 2001*a*), which have been maintained for centuries by human intervention such as coppicing, mowing and farming (Takeuchi, 2003; Ishii, 2001*a*, *b*). *Satoyama* is an important habitat for an abundant variety of wildlife including species endemic to Japan and eastern Asia, although it is secondary in an ecological sense (Ishii, 2001*a*, *b*).

However, the fuel and fertilizer revolutions in the 1960s resulted in the destruction and abandonment of coppices, and a consequent decline of wildlife inhabiting *Satoyama* (*e. g.* Moriyama, 1988; Ishii *et al.*, 1993; Hattori *et al.*, 1995; Tabata, 1997). Habitats for wildlife in *Satoyama* farmlands have also been degraded by paddy field consolidation for the mechanization of agriculture, the use of agricultural chemicals such as insecticides and herbi-

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cides, and abandonment or destruction of thatch fields since the 1960s (Moriyama, 1997; Ishii, 2005). Thus it is recognized that the recent change in land use is a primary cause for the decline of biodiversity in Japan, and indeed many species of wild animals and plants including butterflies in *Satoyama* now appear on Red Data Lists of the Environmental Ministry of Japan and local authorities in Japan. Although no native butterfly species has become extinct in Japan, there has been a considerable net decline of local butterfly populations in *Satoyama* (Ishii, 1996; Nakamura, 2003; Inoue, 2005).

In this study we investigated the butterfly assemblage in different landscape components of a *Satoyama* in northern Osaka, central Japan, and analyzed the relationship between vegetation type and species diversity of butterflies there by using a newly developed index based on seral stages in which the major food plants of each butterfly species occur. From the results, we discuss the characteristics of butterfly assemblage in *Satoyama*, and the conservation of species diversity of butterflies there.

Study site and methods

This study was carried out in a *Satoyama* in and around Mt Mikusa (34°57′N, 135°22′E, 564 m a.s.l.), northern Osaka, central Japan, from April to October, 2004. A nature reserve, "Mt. Mikusa *Zephyrus* Coppice" is situated on the southeastern slope of Mt Mikusa, and a local conservation body has been conducting the management of the coppice. There are remnants of coppice woodlands that are dominated by deciduous oaks, such as *Quercus serrata*, *Q. acutissima*, *Q. aliena*, etc., and farmlands including rice paddies, vegetable fields, chestnut orchards, etc., in this area. We divided the study area into two landscapes, Farm and Coppice, and fixed a transect route through major landscape components in the two landscapes. The transect was divided into 26 sections according to landscape components (Fig. 1). Details of each section are shown in Table 1.

In the Farm landscape, the transect was divided into three sections, corresponding to three landscape components, Plain paddy, Village and Yatsuda (paddy fields developed on a narrow valley bottom). The transect of Plain-paddy section was fixed on a levee between rice paddies on the plain where frequent mowing and grass-burning were conducted and short herbs of Leguminosae and Gramineae dominated. The transect of Village section was fixed along a narrow road through settlements with horticultural plants, plantations of the Japanese cypress, *Chamaecyparis obtuse* (Taxodiaceae), the Japanese cedar, *Cryptomeria japonica* (Cupressaceae), the chestnut *Castanea crenata* (Fagaceae) and the bamboo, *Phyllostachys* sp., gardens, and open space with short and tall herbs, climbing plants and the dwarf bamboo, *Pleioblastus chino* (Gramineae). The transect of the Yatsuda section was fixed along a road surrounded by rice paddies, levees and slopes with short and tall herbs such as *Imperata cylindrica* and *Miscanthus sinensis* (Gramineae), abandoned fields with tall herbs and shrubs such as *M. sinensis* and *Albizzia julibrissin* (Leguminosae), chestnut orchards, Japanese cypress plantations and coppices on the valley bottom.

In the Coppice landscape, the transect was divided into 23 sections belonging to six landscape components, Glade, Cutover-land, Coppice edge, Medium coppice, Tall coppice and Cypress plantation (Fig. 1). All components of the Coppice landscape were dominated by dwarf bamboo with high densities on the forest floor except Cypress plantation. Glade sections (G1 and G2) were along trails through an open grassy slope, where short herbs such as *Clinopodium gracile* (Labiatae) and *Viola grypoceras* (Violaceae), tall herbs such as *Phytolacca americana* (Phytolaccaceae) and *M. sinensis*, and dwarf bamboo 1–3 m in height were dominant. The Cutover-land section (CL) was established in a 4th-year coppice after cutting. The dominant trees were *Q. acutissima* and *Q. aliena* 3–5 m high, and

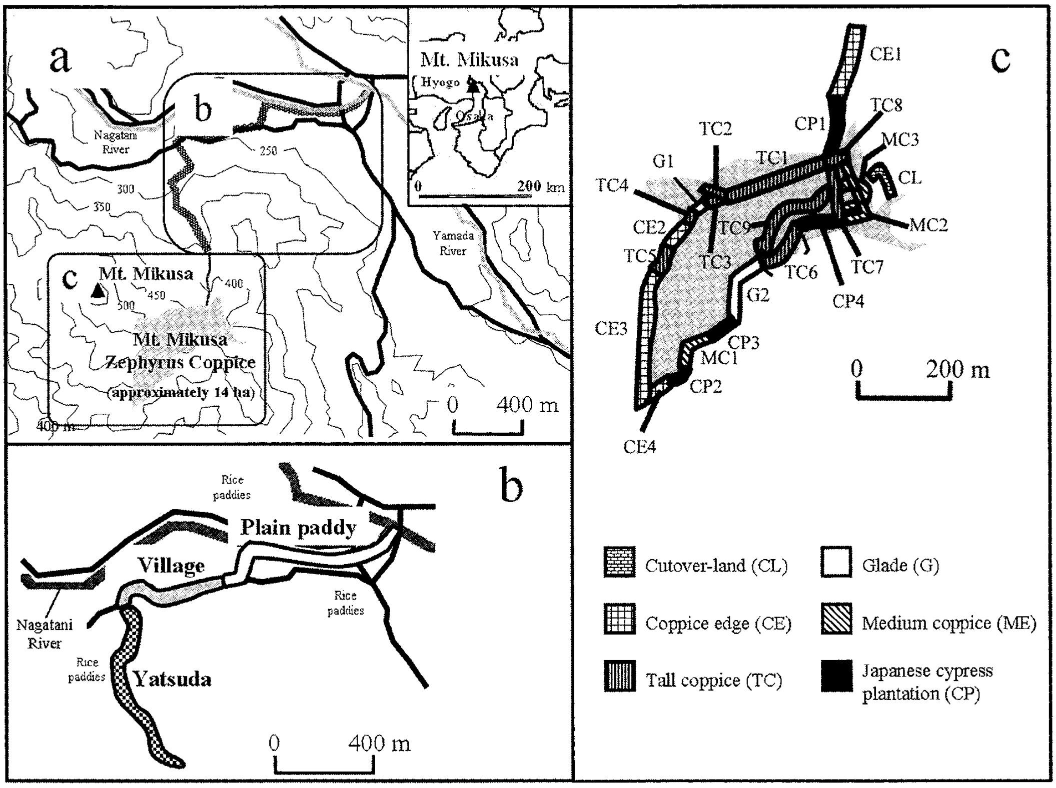

Fig. 1. Location of the study area (a) and transect routes established in Farm (b) and Coppice (c) landscapes in and around Mt Mikusa, northern Osaka, central Japan.

the ground was covered with bushes of dwarf bamboo from 1 to 3 m in height. Coppice-edge sections (CE1–4) were fixed along a trail on the boundary of a chestnut orchard (CE1) or coppices of deciduous oaks (CE2–4) and open space. Sections CE3 and 4 were adjacent to 1st to 3rd-year Cutover-lands dominated by *Q. acutissima* and *Q. aliena*. Medium-coppice sections (MC1–4) were along a trail through coppices consisting of *Q. acutissima* and *Q. aliena* about 10 m in height. Tall-coppice sections (TC1–8) also occurred along a trail through coppices dominated by deciduous oaks, although the mean heights (about 15 m) were taller than those of the Medium-Coppice sections. Cypress-plantation sections (CP1–4) occurred along a trail on boundaries between Japanese cypress plantations (mean height: 18 m) and coppices dominated by deciduous oaks (15 m in height).

Data collection on butterfly assemblages was conducted using the transect method (Pollard, 1977, 1984; Thomas, 1983; Pollard and Yates, 1993). Counts of butterflies were conducted in all sections of the transect throughout the study area a total of 14 times, twice a month from April to October, in 2004. Each count was conducted from 9:30 to 15:00 hrs local time as a rule under fine weather conditions with calm to light winds. We recorded the number of adult individuals of each butterfly species sighted within a 10 m width (5 m each side of the recorder) and up to 5 m height along the transect. Butterflies not readily identified were captured by net and released immediately after identification.

Analysis

Community indices

We calculated species diversity by the Simpson's index of diversity, $1-\lambda$ (Simpson, 1949), and species evenness by the equitability index, J' (Pielou, 1969) as follows:

Table 1. Transect length, altitude and dominant plants in each landscape component in the study area.

Landscape component and section	Dwarf bamboo		Dominant plants (Family)					
	Density	Hight (m)	Short herb	Tall herb	Climbing plant	Shrub	Deciduous tree	Evergreen tree
Farm landscape								
Plain paddy Transect length: 850 m Altitude: 200–220 m Height of tree layer: –	–	–	*Trifolium repens* (Leg), *T. dubium* (Leg), *Imperata cylindrica* (Gra), *Sisyrinchium angustifolium* (Iri)					
Village Transect length: 555 m Altitude: 220–260 m Height of tree layer: 8–18 m	Low	1.5	*Viola grypoceras* (Vio), *Ranunculus cantoniensis* (Ran), *Galium aparine* (Rub), *Saxifraga stolonifera* (Sax)	*Heracleum sphondylium* (Umb), *Miscanthus sinensis* (Gra)	*Lonicera japonica* (Cap), *Hedera rhombea* (Aral), *Akebia quina* (Lar), *Pueraria lobata* (Leg)	*Pleioblastus chino* (Gra), *Hydrangea macrophylla** (Sax), *Rhododendron hirado** (Eri)	*Castanea crenata* (Fag)	*Cryptomeria japonica* (Cup), *Chamaecyparis obtusa* (Tax)
Yatsuda Transect length: 845 m Altitude: 260–360 m Height of tree layer: 5–15 m	Low	1.5	*T. repens*, *T. dubium*, *I. cylindrica*	*H. sphondylium*, *M. sinensis*, *Festuca* spp. (Gra), *Reynoutria japonica* (Pol), *Solidago altissima* (Com)	*L. japonica*, *P. lobata*, *Wistaria floribunda* (Leg), *Dioscorea japonica* (Dio)	*P. chino*, *Rosa multiflora* (Ros), *Rubus palmatus* (Ros), *Deutzia crenata* (Sax), *Albizzia julibrissin* (Leg)	*C. crenata*, *Quercus acutissima* (Fag)	*Cr. japonica*, *Ch. obtusa*
Coppice landscape								
Glade (2 sections) Transect length: 210 m Altitude: 380–460 m Height of tree layer: –	Medium	1.0–3.0	*Clinopodium gracile* (Lab), *Torilis scabra* (Umb), *Stellaria aquatica* (Car), *Cardamine flexuosa* (Cru), *V. grypoceras*	*Phytolacca americana* (Phy), *M. sinensis*	*D. japonica* (Dio)	*P. chino*, *Aralia elata* (Aral)		
Cutover land Transect length: 132 m Altitude: 400–420 m Height of tree layer: 3–5 m	High	1.0–3.0		*Eupatorium chinense* (Com), *M. sinensis*, *P. americana*	*Smilax china* (Lil), *L. japonica* (Cap)	*P. chino* (Gra), *A. elata*, *Zanthoxylum piperitum* (Rut), *R. palmatus*, *Callicarpa japonica* (Ver)	*Q. acutissima*, *Q. aliena* (Fag)	
Coppice edge (4 sections) Transect length: 735 m Altitude: 360–470 m Height of tree layer: 8–16	High	0.5–2.5	*V. grypoceras*, *Viola verecunda* (Vio), *C. flexuosa*, *R. cantoniensis*	*M. sinensis*, *Pteridium aquilinum* (Den)	*D. japonica*, *Cocculus trilobus* (Men)	*P.* chino, *R. multiflora*, *Zanthoxylum ailanthoides* (Rut)	*C. crenata*, *Q. acutissima*, *Q. aliena*	*Pinus densiflora* (Pin), *Ch. obtusa*

Medium coppice (3 sections) Transect length: 548 m Altitude: 380–460 m Height of tree layer: 10 m	High	0.5–1.0	*V. grypoceras*, *Ixeris dentata* (Com), *Gentiana zollingeri* (Gen)	*M. sinensis* (Gra), *P. aquilinum* (Den)	*D. japonica*, *Dioscorea tokoro* (Dio), *W. floribunda*	*P. chino*, *Lindera umbellata* (Lau), *Vaccinium oldhami* (Eri), *Elaeagnus umbellata* (Ela), *Ligustrum obtusifolium* (Ole), *Lonicera gracilipes* (Cap)	*C. crenata*, *Q. acutissima*, *Q. aliena*, *Populus sieboldi* (Sal)	*P. densiflora*
Tall coppice (9 sections) Transect length: 1196 m Altitude: 380–480 m Height of tree layer: 15 m	High	0.5–1.0	*Arisaema serratum* (Arac), *Rubus hirsutus* (Ros), *Viola violacea* (Vio), *V. grypoceras*, *Pertya scandens* (Com)	*P. americana* (Phy)		*P. chino*, *L. umbellata*, *V. oldhami*, *Lyonia ovalifolia* (Eri), *L. gracilipes*, *Ilex pedunculosa* (Aqu)	*C. crenata*, *Q. acutissima*, *Q. aliena*, *Q. serrata* (Fag), *Eleutherococcus sciadophylloides* (Aral), *Prunus jamasakura* (Ros)	*P. densiflora*, *Ch. obtusa*
Cypress plantation (4 sections) Transect length: 370 m Altitude: 380–420 m Height of tree layer: 15 m	Low	0.5–1.0	*V. grypoceras*			*P. chino*, *Eurya japonica* (The)	*Q. acutissima*, *Q. aliena*	*Ch. obtusa*

Family names. Aqu, Aquifoliaceae; Arac, Araceae; Aral, Araliaceae; Cap, Caprifoliaceae; Car, Caryophyllaceae; Com, Compositae; Cru, Cruciferae; Cup, Cupressaceae; Den, Dennstaedtiaceae; Dio, Dioscoreaceae; Ela, Elaeagnaceae; Eri, Ericaceae; Fag, Fagaceae; Gen, Gentianaceae; Gra, Gramineae; Iri, Lab, Labiatae; Lar, Lardizabalaceae; Lau, Lauraceae; Leg, Leguminosae; Lil, Liliaceae; Men, Menispermaceae; Ole, Oleaceae; Phy, Phytolaccaceae; Pin, Pinaceae; Pol, Polygonaceae; Ran, Ranunculaceae; Ros, Rosaceae; Rub, Rubiaceae; Rut, Rutaceae; Sal, Salicaceae; Sax, Saxifragaceae; Tax, Taxodiaceae; The, Theaceae; Umb, Umbelliferae; Ver, Verbenaceae; Vio, Violaceae.

* Horticultural plants.

Table 2. Five seral stages determined in this study, vegetation type and characters of plants in each stage.

Seral stage	Vegetation type	Characters of plants in each seral stage		
		Herb and grass	Climbing plant	Woody plant
1	Short grassland	Short herbs in grassland		
2	Tall grassland	Tall herbs in grassland		
3	Young forest	Tall herbs in young forest	Climbing plants in forest edge	Deciduous shrubs
		Short herbs in edge of deciduous forest		Young deciduous trees
4	Deciduous forest	Tall herbs in deciduous forest	Climbing plants in deciduous forest	Deciduous trees
		Short herbs with relatively high shade torelance		Deciduous shrubs in deciduous forest
				Young evergreen trees
5	Evergreen forest	Herbs in evergreen forest	Climbing plants in evergreen forest	Evergreen trees
				Shrubs in evergreen forest

$$1-\lambda = 1-\Sigma n_i\,(n_i-1)/N\,(N-1)$$

$$J' = -\Sigma\,((n_i/N)\,\log S\,(n/N)$$

where n_i is the number of individuals of the ith species, N is the total number of individuals of all component species, and S is the total number of species.

To group the butterfly assemblages from nine landscape components according to the similarity in species composition or assemblage structures, we conducted UPGMA cluster analyses based on Pianka's α index (Pianka, 1973) as follows:

$$\alpha = (\Sigma\,(n_{1i}n_{2i}))/((\Sigma\,(n_{1i}/N_1)^2\,\Sigma\,(n_{2i}/N_2)^2)^{1/2}N_1N_2)$$

where N_1 and N_2 represent the total number of individuals or species in landscape components 1 and 2, n_{1i} and n_{2i} represent the number of individuals or species of ith species or group in landscape componensts 1 and 2, respectively.

Ecological classification of butterflies and analyses of assemblage structures

We classified butterflies recorded in this study into 2–4 groups according to voltinism and geographical distribution as described in Nishinaka and Ishii (2006). We compared species richness and abundance of each butterfly group between landscapes and among landscape components. In addition, we determined the seral rank (SR) for each butterfly species according to seral stages in which major larval food plants occur, and analyzed butterfly assemblages in the study area by the proportion of each seral rank (SR). Major larval food plants and seral stages in which the plant species occur were determined according to Unno and Aoyama (1981), Fukuda *et al.* (1982, 1983, 1984*a*, *b*), Makino (1982, 1983) and Okuda (1997). Seral stages of vegetation (St) were categorized into five stages (st1–5), according to the successional process in temperate regions in central Japan, short grassland (st1), tall grassland (st2), young forest (st3), deciduous forest (st4) and evergreen forest (st5) (Table 2).

SR for each butterfly species was calculated as follows:

$$SR = 2\,\Sigma\,sti/n-1$$

where st$i$ is the score of ith seral stage (1–5), and n is the total number of seral stages in

which foodplants of the species occur. St and SR for each species are shown in Table 3.

To group butterfly assemblages from nine landscape components with respect to the seral rank of component species, we conducted UPGMA cluster analyses based on Pianka's index α for the evaluation of overlap of species and/or abundance of species belonging to each seral rank.

Results

Characteristics of butterfly assemblage in Farm and Coppice landscapes

A total of 1322 individuals belonging to 56 species from seven families were observed in the study area (Table 4). Out of the 1322 individuals, 412 and 910 individuals belonging to 39 and 46 species were seen in Farm and Coppice landscapes, respectively. Community indices, $1-\lambda$ and J' were higher in Farm landscape (0.91 and 0.75 respectively) than in Coppice landscape (0.85 and 0.66).

The dominant species in the study area were *Lethe diana* (290 individuals), *Neope goschkevitschii* (148), *L. sicellis* (101), *Ypthima argus* (94) and *Colias erate* (69) in decreasing order, and the proportion of the five species was 53% in the number of individuals (Table 4). The top five dominant species in Coppice landscape were all satyrids, the same species as those in the whole study site, except that *Minois dryas* was one of the five dominant species instead of *C. erate*. In contrast, in Farm landscape five dominant species were all grassland species and differed considerably from those in the whole study site: they were *C. erate*, *Lycaena phlaeas*, *Pieris rapae*, *Y. argus* and *Everes argiades* in decreasing order.

Out of the 56 species recorded from the study area, 17 and 10 species were observed only in Coppice and Farm landscape respectively, while 29 were common between the two landscapes (Table 4). Major species unique to Coppice landscape were woodland species such as *Erynnis montanus*, *Naratura japonica*, *Favonius cognatus*, *Argynnis paphia* and *Mycalesis francisca*. On the other hand, openland species such as *C. erate*, *P. rapae*, *Zizeeria maha*, *Cynthia cardui* and *Parnara guttata* were among the major species unique to Farm landscape. The 29 species seen in both landscapes included the species of forest edge such as *Y. argus*, *Pieris melete*, *Neptis sappho*, *Thoressa varia* and *Eurema hecabe*.

The top four dominant species in the study area, *L. diana*, *N. goschkevitschii*, *L. sicellis* and *Y. argus*, were of the Sino-Japanese group, while the fifth dominant species, *C. erate*, was of the Siberian group (Table 4). Besides the dominant species, Sino-Japanese species such as *E. montanus*, *F. cognatus* and *M. francisca* were seen in Coppice landscape, while Siberian species such as *L. phlaeas*, *P. rapae* and *E. argiades* and Malayan species such as *Z. maha*, *C. cardui* and *P. guttata* were abundant in Farm landscape. On the other hand, Sino-Japanese species such as *P. melete*, *T. varia* and *C. acuta*, Siberian species such as *M. dryas* and *N. sappho*, and Malayan species such as *E. hecabe* and *K. canace* were seen in both landscapes. Thus species richness of the Sino-Japanese group (31 spp.) was larger than those of the Siberian (11 spp.) and Malayan (14 spp.) groups in the whole study site, and the proportion of the Sino-Japanese group in species richness was higher in Coppice landscape (65%) than in Farm landscape (51%) (Fig. 2). In density, the proportion of the Sino-Japanese group was much higher in Coppice landscape (83%) than in Farm landscape (29%), where the Siberian species was the most dominant. Furthermore, three out of the 31 Sino-Japanese species were those endemic to Japan, and the proportion in density was larger in Coppice landscape (27%) than in Farm landscape (1%) due to the abundance of *N. goschkevitschii* and *L. sicellis*.

Table 3. The seral rank (SR) of butterfly species recorded in this study. Major larval food plants, and their seral stages are also shown. See text for calculation of SR.

Species name	Major larval food plant (Family)	Seral stage 1	2	3	4	5	SR
Hesperiidae セセリチョウ科							
Erynnis montanus ミヤマセセリ	Deciduous oak (Fag)			+	+		6
Daimio tethys ダイミョウセセリ	Black bryony (Dio)			+			5
Thoressa varia コチャバネセセリ	Dwarf bamboo (Gra)		+	+	+		5
Isoteinon lamprospilus ホソバセセリ	Grass (Gra)		+	+			4
Potanthus flavum キマダラセセリ	Grass (Gra)	+	+	+	+		4
Polytremis pellucida オオチャバネセセリ	Grass (Gra)		+	+	+		5
Pelopidas mathias チャバネセセリ	Grass (Gra)	+	+	+			3
Parnara guttata イチモンジセセリ	Grass (Gra)	+	+	+			3
Papilionidae アゲハチョウ科							
Byasa alcinous ジャコウアゲハ	*Aristolochia* spp. (Ari)		+	+			4
Graphium sarpedon アオスジアゲハ	Camphor tree (Lau)				+	+	8
Papilio xuthus ナミアゲハ	*Zanthoxylum* spp. (Rut)			+			5
P. helenus モンキアゲハ	*Zanthoxylum* spp. (Rut)			+	+		6
P. protenor クロアゲハ	*Zanthoxylum* spp. (Rut)			+			5
P. macilentus オナガアゲハ	Orixa spp. (Rut)			+			5
P. bianor カラスアゲハ	*Zanthoxylum* spp. (Rut)			+	+		6
P. maackii ミヤマカラスアゲハ	*Zanthoxylum* spp. (Rut)			+	+		6
Pieridae シロチョウ科							
Colias erate モンキチョウ	Clover (Leg)	+				+	1
Eurema hecabe キチョウ	Bush clover (Leg)	+	+	+	+	+	4
Anthocharis scolymus ツマキチョウ	Bitter cress (Cru)	+	+	+		+	3
Pieris rapae モンシロチョウ	Cabbage (Cru)	+				+	1
P. melete スジグロシロチョウ	Yellow cress (Cru)	+	+	+		+	3
Lycaenidae シジミチョウ科							
Narathura japonica ムラサキシジミ	Evergreen oak (Fag)			+	+	+	7
*Japonica saepestriata** ウラナミアカシジミ	Deciduous oak (Fag)			+	+		6
*Antigius attilia** ミズイロオナガシジミ	Deciduous oak (Fag)			+	+		6
*Favonius cognatus** ヒロオビミドリシジミ	Deciduous oak (Fag)			+	+		6
Callophrys ferrea コツバメ	Japanese andromeda (Eri)			+	+	+	7
Rapala arata トラフシジミ	*Wistaria* spp. (Leg)			+			5
Taraka hamada[§] ゴイシシジミ	Aphids[§]			+	+		6
Lycaena phlaeas ベニシジミ	Sheep sorrel (Pol)	+					1
Zizeeria maha ヤマトシジミ	*Oxalis* spp. (Oxa)	+					1
Celastrina argiolus ルリシジミ	Kudzu (Leg)		+	+	+	+	6
Everes argiades ツバメシジミ	Tares (Leg)	+	+	+			3
Curetis acuta ウラギンシジミ	Kudzu (Leg)		+	+			4
Libytheidae テングチョウ科							
Libythea celtis テングチョウ	Hackberry (Ulm)			+	+		6
Nymphalidae タテハチョウ科							
*Argyronome ruslana*** オオウラギンスジヒョウモン	Forest Violet (Vio)			+			5
*Damora sagana*** メスグロヒョウモン	Forest Violet (Vio)			+			5
*Nephargynnis anadyomene*** クモガタヒョウモン	Forest Violet (Vio)			+			5
*Argynnis paphia*** ミドリヒョウモン	Forest Violet (Vio)			+			5
*Argyreus hyperbius*** ツマグロヒョウモン	Violet (Vio)	+		+			3
Ladoga camilla イチモンジチョウ	*Lonicera* spp. (Cap)			+			5
L. glorifica アサマイチモンジ	*Lonicera* spp. (Cap)			+			5
Neptis sappho コミスジ	Kudzu (Leg)			+			5
Polygonia c-aureum キタテハ	*Humulus* spp. (Mor)	+	+				2
Kaniska canace ルリタテハ	*Smilax china* (Lil)			+			5
Vanessa indica アカタテハ	Ramie (Urt)		+	+	+		5
Cynthia cardui ヒメアカタテハ	*Artemisia* spp. (Com)	+	+				2

Dichorragia nesimachus スミナガシ	*Meliosma* spp. (Sab)			+	+	+	7
Apatura metis コムラサキ	*Salix babylonica* (Sal)			+	+		6
Satyridae ジャノメチョウ科							
Ypthima argus ヒメウラナミジャノメ	Grass (Gra)	+	+	+			3
Minois dryas ジャノメチョウ	Grass (Gra)		+	+			4
Lethe sicelis ヒカゲチョウ	Dwarf bamboo (Gra)			+	+		6
L. diana クロヒカゲ	Dwarf bamboo (Gra)			+	+		6
Neope goschkevitschii サトキマダラヒカゲ	Dwarf bamboo (Gra)			+	+		6
Mycalesis gotama ヒメジャノメ	Grass (Gra)	+	+	+			3
M. francisca コジャノメ	Grass (Gra)		+	+			4
Melanitis phedima クロコノマチョウ	Grass (Gra)		+	+			4

Family names of larval host plants. Ari, Aristolochiaceae; Cap, Caprifoliaceae; Com, Compositae; Cru, Cruciferae; Dio, Dioscoreaceae; Eri, Ericaceae; Fag, Fagaceae; Gra, Gramineae; Lau, Lauraceae; Leg, Leguminosae; Lil, Liliaceae; Mor, Moraceae; Oxa, Oxalidaceae; Pol, Polygonaceae; Rut, Rutaceae; Sab, Sabiaceae; Sal, Salicaceae; Ulm, Ulmaceae; Urt, Urticaceae; Vio, Violaceae.

§Although *Taraka hamada* is carnivore, we treated this species as "Dowarf bamboo feeder" because larval food is the aphids inhabiting on leaves of dwarf bamboos.

*: Hairstreak species; **: Fritillary species.

Species richness of univoltine species was larger in Coppice landscape (12 spp.) than in Farm landscape (five spp.), and all the univoltine species in Farm landscape were also recorded from Coppice landscape (Table 4). A total of seven univoltine species were recorded only from Coppice landscape included three deciduous oak feeders, *E. montanus*, *J. saepestriata* and *F. cognatus*, three forest-violet feeders, *A. ruslana*, *Nephargynnis anadyomene* and *A. paphia* and a crucifer feeder, *Anthocharis scolymus*.

Characteristics of butterfly assemblage in each landscape component

Species richness of butterflies was different among the nine landscape components: it was highest in Yatsuda (33 spp.), followed by Coppice edge (30), Tall coppice (29), Medium coppice (26), Glade (24) and Village (21), while it was lowest in Cutover-land (11) and Cypress plantation (11) followed by Plain paddy (13) (Table 4). Density of butterflies was higher in Coppice landscape (20.4 individuals/km) than in Farm landscape (13.1) and also different among landscape components. The density was highest in Medium coppice (26.9), followed by Coppice edge (24.2), Glade (21.1), while it was lowest in Village (8.0), followed by Yatsuda (14.1) and Plain Paddy (15.4).

Species diversity ($1-\lambda$) of butterfly assemblage varied largely among landscape components (Table 4). It was highest (>0.90) in three landscape components, Village, Yatsuda and Glade, followed by Cutover-land (0.90) and Coppice edge (0.89), while it was lowest in Cypress plantation (0.55). In Cutover land, not only species diversity but also evenness (J') was high (0.92) irrespective of poor species richness (11 spp.), but the species diversity is overestimated due to the short transect and the lowest abundance (32 individuals). In contrast, species diversity was relatively low (0.76) irrespective of high species richness (29 spp.) in Tall coppice. This is due to the dominance of *L. diana*, as shown by the low eveness (0.63).

The number of species unique to a particular landscape component ("unique species") was the largest in Yatsuda, Glade and Tall coppice (3 spp. each), and they were *Taraka hamada*, *Ladoga glorifica* and *Apatura metis* in Yatsuda, *Polytremis pellucida*, *Byasa alcinous* and *Anthocharis scolymus* in Glade, and *Papilio helenus*, *P. maackii* and *Melanitis phedima* in Tall coppice (Table 4). In addition, *P. xuthus* and *Argyronome ruslana*, *Japonica saepestriata* and *Dichorragia nesimachus*, and *Graphium sarpedon* were unique to Coppice edge,

Table 4. Mean annual counts of each butterfly species per 1 km transect observed in each landscape component of Farm and Coppice landscapes in the study area from April to October in 2004. Annual counts for each species are shown in parentheses.

Species name	V[1)]	D[2)]	Farm: Plain paddy	Village	Yatsuda	**Farm transect**	Coppice: Glade	Cutover-land	Coppice edge	Medium coppice	Tall coppice	Cypress plantation	**Coppice transect**	**Whole study area**
Hesperiidae														
Erynnis montanus	U	SJ	–	–	–	**–**	0.34 (1)	–	0.49 (5)	0.78 (6)	0.84 (14)	–	**0.58 (26)**	**0.34 (26)**
Daimio tethys	M	SJ	–	–	0.08 (1)	**0.03 (1)**	–	1.08 (2)	0.19 (2)	–	–	–	**0.09 (4)**	**0.07 (5)**
Thoressa varia	M	SJ	0.17 (2)	0.64 (5)	1.18 (14)	**0.67 (21)**	1.02 (3)	3.25 (6)	0.58 (6)	0.52 (4)	0.12 (2)	–	**0.47 (21)**	**0.55 (42)**
Isoteinon lamprospilus	U	SJ	–	0.13 (1)	–	**0.03 (1)**	–	–	0.19 (2)	–	–	–	**0.04 (2)**	**0.04 (3)**
Potanthus flavum	M	SJ	–	–	–	**–**	0.34 (1)	–	0.10 (1)	–	0.06 (1)	–	**0.07 (3)**	**0.04 (3)**
Polytremis pellucida	M	SJ	–	–	–	**–**	1.36 (4)	–	–	–	–	–	**0.09 (4)**	**0.05 (4)**
Pelopidas mathias	M	Ma	–	0.13 (1)	0.08 (1)	**0.06 (2)**	–	–	–	–	–	–	**–**	**0.03 (2)**
Parnara guttata	M	Ma	–	0.13 (1)	0.17 (2)	**0.10 (3)**	–	–	–	–	–	–	**–**	**0.04 (3)**
Papilionidae														
Byasa alcinous	M	SJ	–	–	–	**–**	0.34 (1)	–	–	–	–	–	**0.02 (1)**	**0.01 (1)**
Graphium sarpedon	M	Ma	0.08 (1)	–	–	**0.03 (1)**	–	–	–	–	–	–	**–**	**0.01 (1)**
Papilio xuthus	M	SJ	–	–	–	**–**	–	–	0.29 (3)	–	–	–	**0.07 (3)**	**0.04 (3)**
P. protenor	M	SJ	–	0.13 (1)	0.08 (1)	**0.06 (2)**	–	–	–	0.26 (2)	0.12 (2)	0.19 (1)	**0.11 (5)**	**0.09 (7)**
P. helenus	M	Ma	–	–	–	**–**	–	–	–	–	0.06 (1)	–	**0.02 (1)**	**0.01 (1)**
P. macilentus	M	SJ	–	0.39 (3)	–	**0.10 (3)**	0.34 (1)	–	0.10 (1)	0.13 (1)	0.12 (2)	–	**0.11 (5)**	**0.11 (8)**
P. bianor	M	SJ	–	0.13 (1)	–	**0.03 (1)**	–	–	–	–	0.06 (1)	–	**0.02 (1)**	**0.03 (2)**
P. maackii	M	SJ	–	–	–	**–**	–	–	–	–	0.06 (1)	–	**0.02 (1)**	**0.01 (1)**
Pieridae														
Colias erate	M	Si	4.71 (56)	0.13 (1)	1.01 (12)	**2.19 (69)**	–	–	–	–	–	–	**–**	**0.91 (69)**
Eurema hecabe	M	Ma	–	0.26 (2)	0.59 (7)	**0.29 (9)**	0.34 (1)	0.54 (1)	0.29 (3)	0.39 (3)	0.36 (6)	0.19 (1)	**0.34 (15)**	**0.32 (24)**
Anthocharis scolymus	U	SJ	–	–	–	**–**	0.34 (1)	–	–	–	–	–	**0.02 (1)**	**0.01 (1)**
Pieris rapae	M	Si	2.69 (32)	0.64 (5)	0.68 (8)	**1.43 (45)**	–	–	–	–	–	–	**–**	**0.59 (45)**
P. melete	M	SJ	–	1.80 (14)	0.93 (11)	**0.79 (25)**	3.06 (9)	0.54 (1)	1.07 (11)	0.39 (3)	0.42 (7)	0.19 (1)	**0.72 (32)**	**0.75 (57)**
Lycaenidae														
Narathura japonica	M	Ma	–	–	–	**–**	0.68 (2)	–	0.39 (4)	–	0.12 (2)	–	**0.18 (8)**	**0.11 (8)**
Japonica saepestriata	U	SJ	–	–	–	**–**	–	–	–	0.26 (2)	–	–	**0.04 (2)**	**0.03 (2)**
Antigius attilia	U	SJ	–	–	0.08 (1)	**0.03 (1)**	–	–	0.39 (4)	0.65 (5)	0.36 (6)	–	**0.34 (15)**	**0.21 (16)**
Favonius cognatus	U	SJ	–	–	–	**–**	–	–	0.29 (3)	0.65 (5)	0.12 (2)	–	**0.22 (10)**	**0.13 (10)**
Callophrys ferrea	U	SJ	–	–	0.08 (1)	**0.03 (1)**	–	–	–	0.13 (1)	–	–	**0.02 (1)**	**0.03 (2)**
Rapala arata	M	SJ	–	–	0.08 (1)	**0.03 (1)**	–	–	0.10 (1)	0.13 (1)	–	–	**0.04 (2)**	**0.04 (3)**
Taraka hamada	M	Ma	–	–	0.08 (1)	**0.03 (1)**	–	–	–	–	–	–	**–**	**0.01 (1)**
Lycaena phlaeas	M	Si	3.28 (39)	0.13 (1)	1.69 (20)	**1.90 (60)**	–	–	0.58 (6)	–	–	–	**0.13 (6)**	**0.87 (66)**

Zizeeria maha	M	Ma	2.02 (24)	0.39 (3)	0.17 (2)	**0.92 (29)**	–	–	–	–	–	–	**–**	**0.38 (29)**
Celastrina argiolus	M	Si	–	0.13 (1)	0.34 (4)	**0.16 (5)**	0.34 (1)	–	0.10 (1)	0.13 (1)	0.06 (1)	–	**0.09 (4)**	**0.12 (9)**
Everes argiades	M	Si	1.43 (17)	–	1.52 (18)	**1.11 (35)**	0.34 (1)	–	–	–	–	–	**0.02 (1)**	**0.47 (36)**
Curetris acuta	M	SJ	–	0.13 (1)	0.42 (5)	**0.19 (6)**	0.68 (2)	–	0.10 (1)	0.52 (4)	–	0.19 (1)	**0.18 (8)**	**0.18 (14)**
Libytheidae														
Libythea celtis	M	SJ	0.08 (1)	–	–	**0.03 (1)**	0.34 (1)	–	–	–	0.12 (2)	–	**0.07 (3)**	**0.05 (4)**
Nymphalidae														
Argyronome ruslana	U	SJ	–	–	–	**–**	–	–	0.10 (1)	–	–	–	**0.02 (1)**	**0.01 (1)**
Damora sagana	U	SJ	–	0.13 (1)	0.08 (1)	**0.06 (2)**	0.68 (2)	0.54 (1)	0.19 (2)	0.39 (3)	0.24 (4)	–	**0.27 (12)**	**0.18 (14)**
Nephargynnis anadyomene	U	Si	–	–	–	**–**	–	–	0.10 (1)	–	0.06 (1)	–	**0.04 (2)**	**0.03 (2)**
Argynnis paphia	U	Si	–	–	–	**–**	–	–	0.19 (2)	0.13 (1)	0.12 (2)	–	**0.11 (5)**	**0.07 (5)**
Argyreus hyperbius	M	Ma	0.08 (1)	0.13 (1)	0.08 (1)	**0.10 (3)**	–	–	–	–	0.06 (1)	–	**0.02 (1)**	**0.05 (4)**
Ladoga camilla	M	Si	–	0.13 (1)	0.17 (2)	**0.10 (3)**	0.34 (1)	–	0.39 (4)	–	0.06 (1)	0.39 (2)	**0.18 (8)**	**0.14 (11)**
L. glorifica	M	SJ (Je)	–	–	0.17 (2)	**0.06 (2)**	–	–	–	–	–	–	**–**	**0.03 (2)**
Neptis sappho	M	Si	–	0.90 (7)	0.76 (9)	**0.51 (16)**	1.02 (3)	1.62 (3)	1.07 (11)	0.65 (5)	0.24 (4)	0.39 (2)	**0.63 (28)**	**0.58 (44)**
Polygonia c-aureum	M	SJ	0.17 (2)	–	–	**0.06 (2)**	–	–	–	0.13 (1)	–	–	**0.02 (1)**	**0.04 (3)**
Kaniska canace	M	Ma	–	–	0.08 (1)	**0.03 (1)**	0.34 (1)	–	0.10 (1)	–	0.06 (1)	–	**0.07 (3)**	**0.05 (4)**
Vanessa indica	M	Ma	–	–	0.08 (1)	**0.03 (1)**	–	–	0.10 (1)	0.13 (1)	–	–	**0.04 (2)**	**0.04 (3)**
Cynthia cardui	M	Ma	0.17 (2)	–	0.25 (3)	**0.16 (5)**	–	–	–	–	–	–	**–**	**0.07 (5)**
Dichorragia nesimachus	M	Ma	–	–	–	**–**	–	–	–	0.13 (1)	–	–	**0.02 (1)**	**0.01 (1)**
Apatura metis	M	Si	–	–	0.08 (1)	**0.03 (1)**	–	–	–	–	–	–	**–**	**0.01 (1)**
Satyridae														
Ypthima argus	M	SJ	0.42 (5)	1.16 (9)	2.20 (26)	**1.27 (40)**	2.72 (8)	1.62 (3)	1.85 (19)	1.82 (14)	0.60 (10)	–	**1.21 (54)**	**1.23 (94)**
Minois dryas	U	Si	0.08 (1)	–	0.17 (2)	**0.10 (3)**	0.34 (1)	1.08 (2)	3.69 (38)	2.09 (16)	0.42 (7)	0.19 (1)	**1.45 (65)**	**0.89 (68)**
Lethe sicelis	M	SJ (Je)	–	–	0.08 (1)	**0.03 (1)**	1.70 (5)	3.25 (6)	2.53 (26)	2.35 (18)	1.67 (28)	3.28 (17)	**2.24(100)**	**1.33(101)**
L. diana	M	SJ	–	0.26 (2)	0.25 (3)	**0.16 (5)**	2.72 (8)	1.08 (2)	3.21 (33)	7.56 (58)	7.47(125)	11.39(59)	**6.38(285)**	**3.81(290)**
Neope goschkevitschii	M	SJ (Je)	–	–	0.25 (3)	**0.10 (3)**	1.02 (3)	2.71 (5)	5.34 (55)	6.00 (46)	1.79 (30)	1.16 (6)	**3.25 (145)**	**1.94(148)**
Mycalesis gotama	M	SJ	–	–	0.08 (1)	**0.03 (1)**	–	–	0.10 (1)	0.39 (3)	–	–	**0.09 (4)**	**0.07 (5)**
M. francisca	M	SJ	–	–	–	**–**	0.34 (1)	–	–	0.13 (1)	0.24 (4)	0.19 (1)	**0.16 (7)**	**0.09 (7)**
Melanitis phedima	M	Ma	–	–	–	**–**	–	–	–	–	0.06 (1)	–	**0.02 (1)**	**0.01 (1)**
Species richness			13	21	33	**39**	24	11	30	26	29	11	**46**	**56**
Annual count			183	62	167	**412**	62	32	249	206	269	92	**910**	**1322**
Count/km			15.4	8.0	14.1	**13.1**	21.1	17.3	24.2	26.9	16.1	17.8	**20.4**	**17.4**
$1-\lambda$			0.81	0.91	0.93	**0.91**	0.94	0.90	0.89	0.85	0.76	0.55	**0.85**	**0.91**
J'			0.72	0.85	0.83	**0.75**	0.89	0.92	0.76	0.73	0.63	0.52	**0.66**	**0.74**

[1] Voltinism: U; univoltine , M; multivoltine.

[2] Geographical distribution: SJ; Sino-Japanese (Eastern Asia including Japan), Je; endemic to Japan, Ma; Malayan (Malaysia, Indonesia and south China), Si; Siberian (widely in the Palaearctic region).

Medium coppice and Plain paddy, respectively. In contrast, no unique species was found in Village, Cutover-land and Cypress plantation.

Numbers of univoltine species were high in Coppice edge (9 spp.), Medium (8) and Tall coppices (7), and low in Cutover-land (2) and Cypress plantation (1) (Table 4, Fig. 3). Density of univoltine species was high at Coppice edge and Medium coppice: in particular, the density of *M. dryas* was high in the two landscape components. In Tall coppice, the density of *E. montanus*, one of the deciduous oak feeders, was the highest.

The dominant species differ among the nine landscape components, although they were fairly similar to each other in landscape components in Coppice landscape (Table 4): two or three species of the three dwarf-bamboo feeding satyrids, *L. diana*, *N. goschkevitschii* and *L. sicellis*, were among the top four dominant species in all six landscape components in Coppice landscape, while they were subordinate or absent in three landscape components in Farm landscape. In contrast, none of the dominant species were common among the three landscape components in Farm landscape: *C. erate*, *L. phlaeas* and *E. argiades* were the dominant species common to Plain paddy and Yatsuda, while *Y. argus* and *T. varia* were common to Village and Yatsuda. It is interesting that *P. melete* and *Y. argus* were the top two dominant species common to Village in Farm landscape and Glade in Coppice landscape, and *Y. argus* was the dominant species among all the landscape components except for Plain paddy and Cypress plantation.

Figure 4 shows a dendrogram indicating the relationship among butterfly assemblages in nine landscape components based on the UPGMA cluster analysis using Pianka's index α. The dendrogram can be grouped into three clusters at the level of 0.5 in α, a cluster of Plain paddy, that of Glade, Village and Yatsuda, and that consisting of the remaining landscape components. The result may be reflected by the composition of dominant species.

Analysis of butterfly assemblages according to seral rank

Fifty-six butterfly species recorded from the study area were classified into eight seral groups, SR1-8 (Table 3). The groups of intermediate seral ranks, SR5 (16 spp.), SR6 (14), SR4 (8) and SR3 (8), were dominant in species richness in the study area, while those of high and low ranks, SR 8 (1), SR2 (2), SR7 (3) and SR1 (4), subordinate (Table 5). In density, SR6 species were the most dominant in Coppice landscape and the whole study area, while SR1 prevailed in Farm landscape (Fig. 5).

Table 5 and Fig. 5 show the distribution of butterflies belonging to each seral rank in nine landscape components in the study area. All species of low rank groups, SR1 and SR2, were abundant in Farm landscape, while they were poor in Coppice landscape. In particular, densities of all four SR1 species, *C. erate*, *P. rapae*, *L. phlaeas* and *Z. maha*, were highest in Plain paddy. In contrast, species of SR6 including three arboreal thecline lycaenids, *J. saepestriata*, *A. attilia* and *F. cognatus*, the oak hesperiid, *E. montanus*, and three dwarf-bamboo feeding satyrids, *L. diana*, *L. sicellis* and *N. goschkevitschii*, were mainly observed in Coppice landscape, although half of them (7 spp.) were seen also in Yatsuda of Farm landscape. In particular, densities of three dwarf-bamboo feeder satyrids were remarkably high in all landscape components in Coppice landscape.

Many species of intermediate rank groups, SR3–5, were observed in both Farm and Coppice landscapes. However, in SR3 species, two hesperiids, *P. mathias* and *P. guttata*, were recorded only from Farm landscape, and the lycaenid, *E. argiades*, and the fritillary, *A. hyperbius*, were more abundant in Farm landscape. In contrast, the hesperiid, *P. flavum*, the satyrid, *M. francisca* (SR4), and two fritillaries, *N. anadyomene* and *A. paphia* (SR5), were

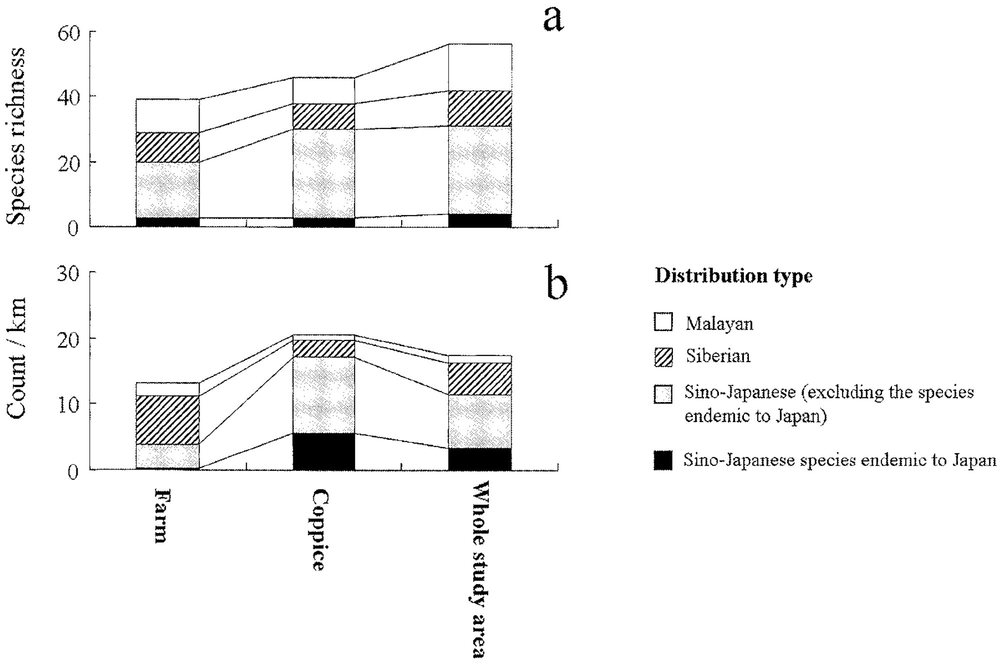

Fig. 2. Species richness (a) and density (counts per km) (b) of four types of butterflies classified by the distribution, Malayan, Siberian, and Sino-Japanese types, and the one endemic to Japan in two landscapes and throughout the whole study area.

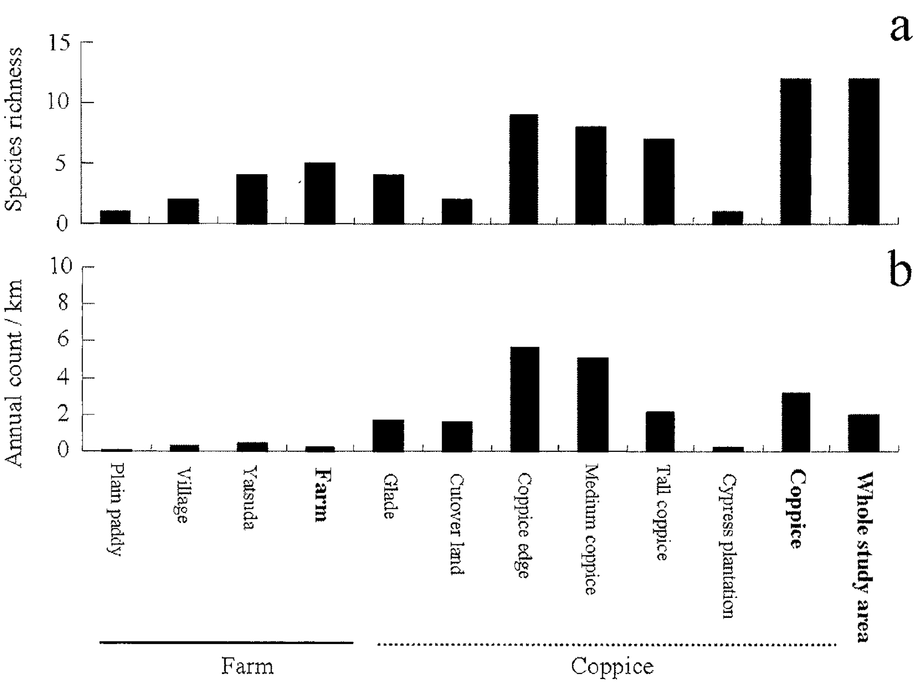

Fig. 3. Species richness (a) and density (counts per km) (b) of univoltine butterflies in two landscapes, nine landscape components and throughout the whole study area.

Table 5. Densities of butterfly species belonging to each SR in each landscape component of the study area. +: <1, ++: 1–2, +++: >2 individuals per km.

Species name				Coppice					
	Plain paddy	Village	Yatsuda	Glade	Cutover-land	Coppice edge	Medium coppice	Tall coppice	Cypress plantn
SR1									
C. erate	+++	+	++						
P. rapae	+++	+	+						
L. phlaeas	+++	+	++			+			
Z. maha	+++	+	+						
SR2									
P. c-aureum	+						+		
C. cardui	+		+						
SR3									
P. mathias		+	+						
P. guttata		+	+						
A. scolymus				+					
P. melete		++	+	+++	+	++	+	+	+
E. argiades	++		++	+					
A. hyperbius	+	+	+					+	
Y. argus	+	++	+++	+++	++	++	++	+	
M. gotama			+			+	+		
SR4									
I. lamprospilus		+				+			
P. flavum				+		+		+	
B. alcinous				+					
E. hecabe		+	+	+	+	+	+	+	+
C. acuta		+	+	+		+	+		+
M. francisca				+			+	+	+
M. dryas	+		+	+	++	+++	+++	+	+
M. phedima								+	
SR5									
D. tethys			+		++	+			
T. varia	+	+	++	++	+++	+	+	+	
P. pellucida				++					
P. xuthus						+			
P. protenor		+	+				+	+	+
P. macilentus		+		+		+	+	+	
R. arata			+			+	+		
A. ruslana						+			
D. sagana		+	+	+	+	+	+	+	
N. anadyomene						+		+	
A. paphia						+	+	+	
L. camilla		+	+	+		+		+	+
L. glorifica			+						
N. sappho		+	+	++	++	++	+	+	+
K. canace			+	+		+		+	
V. indica			+			+	+		
SR6									
E. montanus				+		+	+	+	
P. helenus								+	
P. bianor		+						+	
P. maackii								+	
J. saepestriata							+		
A. attilia			+			+	+	+	
F. cognatus						+	+	+	

T. hamada			+						
C. argiolus		+	+	+		+	+	+	
L. celtis	+			+				+	
A. metis			+						
L. sicelis			+	++	+++	+++	+++	++	+++
L. diana		+	+	+++	++	+++	+++	+++	+++
N. goschkevitschii			+	++	+++	+++	+++	++	++
SR7									
N. japonica				+		+		+	
C. ferrea			+				+		
D. nesimachus							+		
SR8									
G. sarpedon	+								

among species abundant only in Coppice landscape. On the other hand, several species were recorded from almost all landscape components: The pierids, *P. melete* (SR3) and *E. hecabe* (SR4), and the satyrid, *Y. argus*, and the hesperiid, *T. varia* (SR4), were abundant in both Farm and Coppice landscapes. The pampas-grass satyrid, *M. dryas* (SR4), and the nymphalid, *N. sappho* (SR5), were observed in both landscapes, but were more abundant in Coppice landscape.

Species richness of high rank groups, SR7 and SR8, was poor in the study area. A total of eight individuals of the lycaenid, *N. japonica* (SR7) were seen in three landscape components of Coppice landscape, and only one individual of the nymphalid, *D. nesimachus* (SR7) was seen in Medium coppice. Only one individual of the lycaenid, *C. ferrea* (SR7) was observed in each of Yatsuda and Medium coppice, respectively. The papilionid, *Graphium sarpedon*, the only species of SR8, was observed once in Plain paddy of Farm landscape.

Butterfly assemblages in nine landscape components were grouped into two clusters at a level between 0.6 and 0.8 in Pianka's α according to the similarity in composition of species belonging to each seral rank (Fig. 6a): the assemblage in Plain paddy was remarkably different from those of the remaining eight landscape components. The results may be due to the richness of SR1–3 species, existence of a SR8 species (*G. sarpedon*) and poorness/non-existence of SR4–7 species in Plain paddy. When the number of individuals was taken into account, they were grouped into three clusters at the same level (Fig. 6b); clusters of Plain paddy, Yatsuda and Village, and the remaining six landscape components. The results may reflect the dominance of SR1 species in Plain paddy, and the similarlity in composition of species belonging to early to middle seral ranks.

Discussion

Characteristics of butterfly assemblages in Farm and Coppice landscapes

In this study, an abundant variety of butterfly species (56 spp.) was found in a small area of *Satoyama* in and around Mt Mikusa, northern Osaka during the study period. Species richness was high both in Farm (39 spp.) and Coppice landscapes (46 spp.). A total of 62 species of butterflies had been previously recorded from the coppice of Mt Mikusa in our previous studies (Ishii *et al.*, 1995, 2003; Nishinaka and Ishii, 2006). Out of the 56 species observed in this study four species, *T. hamada*, *D. nesimachus*, *A. metis* and *P. mathias*, were newly recorded from the study area, so that the total number of butterfly species in this area has increased to 66 species. The former three are forest species, while *P. mathias* is an

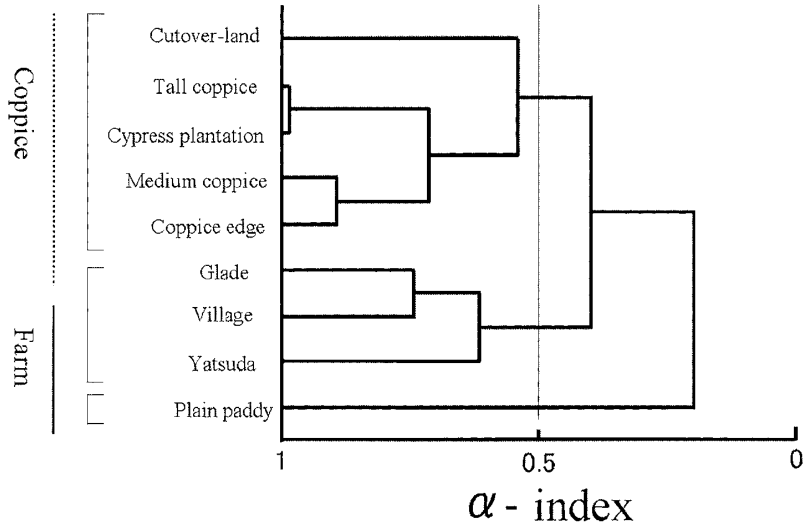

Fig. 4. A dendrogram constructed by results of UPGMA cluster analysis based on the overlap of butterfly assemblages using Pianka's α among nine landscape components in the study area.

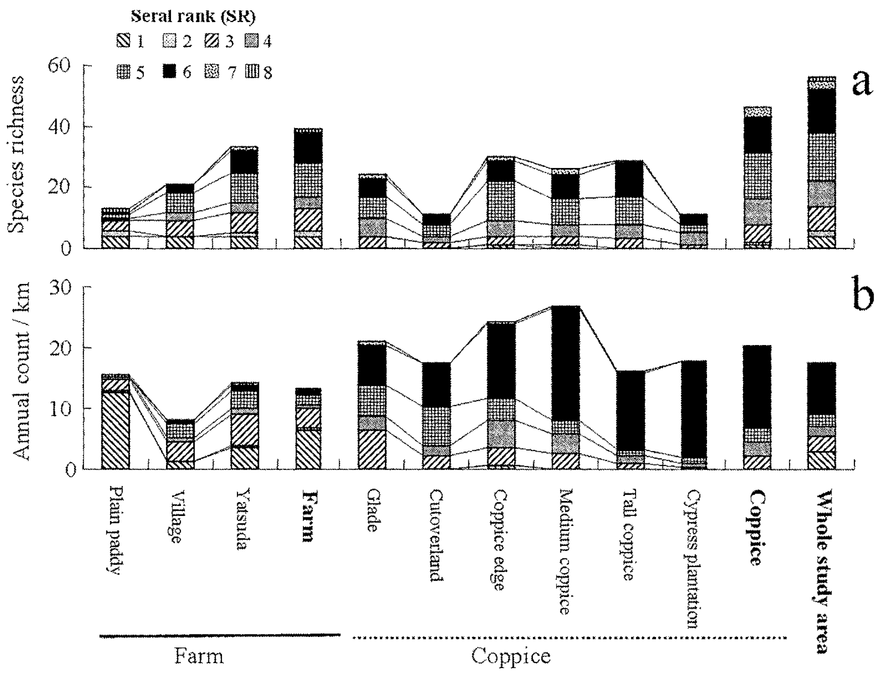

Fig. 5. Species richness (a) and annual counts per km (b) of butterflies belonging to each seral rank in two landscapes, nine landscape components and throughout the whole study area.

openland species dependent on grasses around paddies. The 56 species observed in this study included five species that are endangered in Osaka Prefecture, *F. cognatus*, *J. saepestriata*, *A. ruslana*, *N. anadyomene* and *D. nesimachus* (Osaka Prefecture, 2000).

The butterfly assemblage in the study area was proved to be characterized by the abundance of univoltine species including four of the local red species mentioned above, *F. cognatus*, *J. saepestriata*, *A. ruslana* and *N. anadyomene*. All 12 univoltine species observed in this study are those dependent on plants in *Satoyama* such as deciduous oaks, forest violets and the pampas grass. Considering that univoltine butterfly species are declining in urbanized

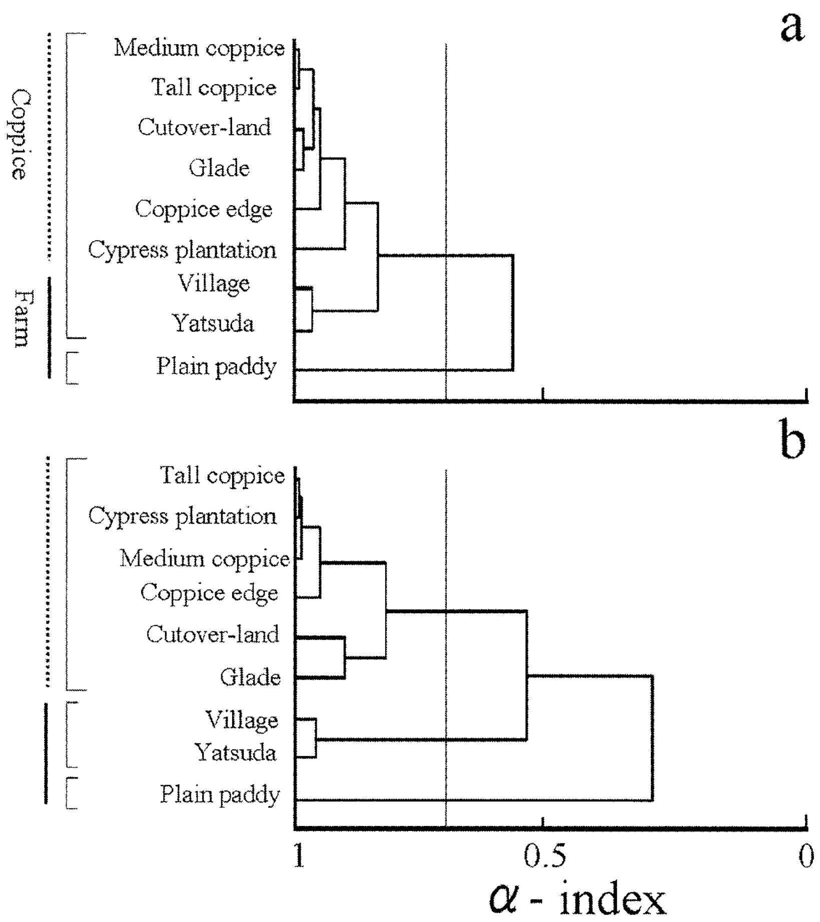

Fig. 6. Dendrograms constructed by results from the UPGMA cluster analysis based on the overlap of species (a) and the abundance of species (b) belonging to each seral rank using Pianka's α among nine landscape components.

areas in Japan (*e. g.* Hiura, 1976; Imai, 1998; Ishii, 2001*a*), their habitats have remained stable in *Satoyama* of the study area.

The results also revealed that Sino-Japanese species including species endemic to Japan were abundant in both species richness and density especially in Coppice landscape of the study area. The butterfly assemblage of Coppice landscape was characterized by the dominance of three dwarf-bamboo feeding satyrids of the Sino-Japanese group, *L. diana*, *N. goschkevitschii* and *L. sicellis*, and the latter two species were endemic to Japan. The three satyrids have been consistently dominant in Mt Mikusa *Zephyrus* Coppice despite occasional mowing of undergrowth including dwarf-bamboo since the investigation of butterfly assemblage began in 1992 (Ishii *et al.*, 1995, 2003; Nishinaka and Ishii, 2006). Besides the three satyrids, 28 butterfly species were also among the Sino-Japanese species recorded in the study area, although they are also declining in urbanized areas (Hiura, 1976; Imai, 1998; Ishii, 2001*b*). Sino-Japanese butterfly species inhabiting present day coppices are considered to have survived in the semi-natural habitats maintained by human intervention from the last ice age when temperate broad-leaved deciduous forests were widely distributed over lowlands in central Japan (Ishii, 2001*b*). The results of this study may support this hypothesis. Thus the butterfly assemblage in the study area consisted of an abundant variety of species in terms of scarcity, voltinism, distribution, and food resources.

Importance of the mosaic of various seral stages of vegetation in the *Satoyama* as a habitat for butterflies

The results show that none of the 56 species recorded in this study was uniformly distributed over the study area, so that the species composition of butterflies was different among landscape components. The butterfly assemblage in Farm landscape was characterized by the dominance of short-herb feeding species including 10 unique species such as *C. erate*, *P. rapae* and *Z. maha*. In contrast, that in Coppice landscape was dominated by the abovementioned dwarf-bamboo feeding satyrids with 17 unique species such as *E. montanus*, *P. maackii* and *F. cognatus*. Moreover, such species as *Y. argus*, *P. melete* and *T. varia* were among those dominant in both Farm and Coppice landscapes.

Several authors have pointed out that factors such as the distribution of nectar sources (*Loertscher et al.*, 1995) and shelter (Dover *et al.*, 1997), and canopy structures (Warren, 1985; Greatorex-Davies *et al.*, 1993; Chikamatsu *et al.*, 2002) affect the microdistribution of adult butterflies. The analysis based on the SR index in this study showed the importance of the seral stage of vegetation as a factor affecting the microdistribution of each butterfly species in *Satoyama*: species of intermediate to high seral ranks such as dwarf-bamboo feeding satyrids, arboreal theclines and forest-violet fritillaries dependent on plants in deciduous broad-leaved forests were abundant mainly in Coppice landscape, while those of low rank such as *C. erate*, *L. phlaeas* and *E. argiades*, dependent on openland grasses, were abundant in Farm landscape. On the other hand, some species of intermediate rank such as *P. melete*, *Y. argus*, *M. dryas* and *T. varia* showed a wide range of distribution in Farm and Coppice landscapes throughout the study area. The results demonstrate that Satoyama consists of a mosaic of vegetation in terms of the seral stage, and plants in different seral-stages provide different butterfly species with foodplants, nectar sources, roosting sites and so on.

The results of cluster analyses showed that the butterfly assemblage of Plain paddy was remarkably different from those of other landscape components in the study area. This may be due to the dominance of *C. erate* and *P. rapae* in Plain paddy. The two species are from the Siberian group, and appeared to depend on alien leguminous herbs, *Trifolium repens* and *T. dubium*, and wild and cultivated cruciferous plants, respectively in the Farm landscape. After the paddy field consolidation that began in the 1960s, alien plants like *Trifolium* species have become more abundant in levees of reconstructed paddies than in those of traditional ones (Yamaguchi *et al.*, 1998).

On the other hand, grassland species dependent on native short herbs such as the fritillary, *Fabriciana nerippe*, the pierid, *Eurema laeta* and the lycaenid *Zizina otis*, which had been seen in *Satoyama* in northern Osaka until the 1960s (Sunose and Eda, 2003), were not found in this study. Butterflies dependent on plants in short grasslands such as *F. nerippe* and the lycaenid, *Shijimiaeoides divinus*, have disappeared from most parts of Japan following abandonment or destruction of grasslands such as thatch fields and consequent fragmentation of their habitats everywhere in Japan (Ishii, 1996). The results of this study suggest that habitats for grassland butterflies in the Farm landscape have been degraded by declining foodplant populations following the recent change in land use including the abandonment and consolidation of paddies.

Many insect groups, including butterflies, are useful biological indicators for evaluation of the natural environment (Erhardt, 1985; Samways, 1994). In particular, butterflies are ideal animals for ecological study (*e. g.* Kudrna, 1986; Ishii, 1993) and important flagship taxa for invertebrate conservation (New *et al.*, 1995). In temperate regions such as Europe and Japan, butterfly taxonomy, food resources of larvae and adults, and life histories are well studied and most species can be identified in the field (*e. g.* Kudrna, 1986; Ishii, 1993). In

addition, there have been many studies on the effects of vegetation type (Erhardt, 1985; Nakamura, 2001; Simonson *et al.*, 2001), vegetation or landscape structures (Weibull et al., 2000; Schneider and Fry, 2001; Krauss *et al.*, 2003; Dennis, 2004), urbanization (Kitahara and Fujii, 1994; Blair and Launer, 1997), secondary succession (New, 1997; Greatorex-Davies *et al.*, 1993; Warren, 1993; Steffan-Dewenter and Tscharntke, 1997; Sanford, 2002; Inoue, 2003), etc., on butterfly populations, faunas and assemblages.

The results of this study also demonstrate that butterflies are useful as a biological indicator group: the analyses of butterfly assemblages by using the SR index revealed that butterflies dependent on plants of a wide range of seral stages inhabit *Satoyama*. It is necessary to maintain a mosaic of a variety of vegetation types in *Satoyama* in terms of the seral stage, to conserve the species diversity of butterflies there. To this end, monitoring of butterflies and analyses of the assemblages by using the SR index are useful tools for the adaptive management of vegetation in *Satoyama*.

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摘　要

チョウ類の重要なハビタットとしての日本の伝統的田園景観「里山」におけるさまざまな遷移系列の植生モザイク (西中康明・石井　実)

大阪府北部の三草山周辺に広がる伝統的田園景観 “里山” の農村および里山林景観において, 2004年の4月から10月にかけて, トランセクト法によるチョウ類群集の調査を行った. これら2つの景観は, 植生構造に基づき複数の景観要素に分けた. すなわち, 農村景観のトランセクトについては平地水田, 山麓集落および谷津田の3種, 里山林景観については林間草地, 皆伐跡地, 林縁, 中木林, 高木林, ヒノキ植林地の6種の景観要素に分けた. そして, 2つの景観および9つの景観要素の間で, チョウ類の群集構造の比較を行った. チョウ類群集の構造の解析には, 各種の主要な寄主植物の出現する遷移段階に基づいて算出した “遷移ランク (SR)” を用い (Table 3参照), 各々のSRに属する種の種数や個体数の構成について, 景観間および景観要素間で比較を行った.

調査の結果, 調査地全体から合計7科56種1322個体のチョウ類が記録された. 種数および密度については里山林景観 (46種, 20.4個体/km) が農村景観 (39種, 13.1個体/km) より大きかったが, 種多様度指数 ($1-\lambda$) や均衡性指数 (J') は農村景観 (それぞれ0.91, 0.75) が里山林景観 (0.85, 0.66) より高かった. 里山林の各景観要素については, 3種のササ食者 (クロヒカゲ, ヒカゲチョウ, サトキマダラヒカゲ) の密度が高いという共通の特徴がみられた. また, 里山林景観では農村景観と比べて1化性の種が多く (それぞれ12種, 5種) , 特にイネ科草本や森林性スミレ類, 落葉性カシ類を寄主とする種の密度が高かった. SR指数に基づく群集構造の解析では, 農村景観の各要素においては, モンキチョウ, モンシロチョウ, ベニシジミなど低茎から高茎草原に出現する寄主植物に依存する種の密度が高かったのに対して, 里山林景観においては, コミスジ, クロヒカゲ, サトキマダラヒカゲなど落葉広葉樹林に出現する寄主植物に依存する種の密度が高かった. また, ヒメウラナミジャノメやスジグロシロチョウ, コチャバネセセリのように, 高茎草原から若齢林に出現する寄主植物に依存する種には, 両景観で個体数の

多いものもみられた.

以上のように, 里山には低茎草原から落葉広葉樹林までの幅広い遷移系列の植生に依存するさまざまなタイプのチョウ類群集が存在することが示された. また, 農村, 里山林それぞれの景観に強く依存するチョウ類に加え, 両景観に共通する種も少なくないことから, さまざまな遷移系列の植生のモザイクを維持することは, 里山のチョウ類の種多様性を保全する上で重要であるといえる.

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